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PHYSICS.—*On the theory of irreversible time effects.*[1] MAYO D. HERSEY, Massachusetts Institute of Technology.

The study of irreversible phenomena has never been carried far in comparison with other aspects of physics. This paper aims to formulate the problem of time effects—meaning transient or recoverable effects as distinguished from permanent changes— and to develop methods of analysis for use in subsequent research. The writer's attention was directed to the importance of this subject in consequence of aneroid barometer investigations[2] at the Bureau of Standards in 1911.

General formulation. When a load X is suddenly applied to an imperfectly elastic body, a certain amount of displacement, x_e, takes place at once, if ordinary inertia effects are excluded. This may be termed the elastic part of the displacement and written $x_e = X/E$, where E denotes the stiffness of the body. But the actual displacement x at any time t differs from this by some small amount y which may be termed the inelastic yield, so that

$$x = X/E + y \qquad (1)$$

The yield, y, depends on the whole past history of the loading of the body and so the displacement at any present time t depends on the load history $X = \text{funct}\ (\tau)$ for all previous times $\tau < t$.

An absolutely general formulation of the problem of irreversible time effects is, therefore, having given the load-time curve, to deduce the displacement-time curve. When the problem has been solved in this general way the solution will be found to embrace, as particular cases, all such special effects as the discrepancy between static and dynamic modulus; residual displacement after removal of load; phase difference between a periodically varying load and the corresponding displacement; time needed for approaching the cyclic state—a state

[1] Received February 26, 1921.

[2] Described in Phys. Rev. 6: 75–76. 1915. It is hoped opportunity will be available later for a more extended report on irreversibility, including a detailed discussion of experimental data already collected. The present paper is intended only as a brief abstract of the principles involved.

in which the hysteresis loop has an invariable form; or the damping of free vibrations. For example, the displacement-load diagram for a given method of loading, $x = \text{funct}\ (X)$, and the hysteresis loop can at once be found by eliminating the time between the load-time curve and the displacement-time curve.

This formulation need not be restricted to elastic lag phenomena. It applies to all irreversible effects measured by some quantity x whose value is fixed by the history of some other quantity X. Thus x might be termed the generalized displacement and X the generalized load. The latter is a more flexible concept than generalized force, because the product Xdx need not represent work. Table 1 shows some of the possible applications of this method.

TABLE 1.—IRREVERSIBLE TIME EFFECTS

Phenomenon	Generalized load, X	Generalized displacement, x
Calibration of aneroid barometer	Change of air pressure	Deflection of instrument pointer
Elastic after-effect with torsion	Torque	Angle of twist
Magnetic hysteresis	Magnetizing force	Induction
Residual charge of condenser	E. M. F.	Quantity of charge
Action of selenium cell	Intensity of incident light	Change of resistance
Hysteresis of thermometer glass	Change of temperature	Change of volume

In what follows the terms load and displacement will be used for short to designate X and x respectively, but it is to be understood that all quantities retain their most general significance. The analysis will be confined to the determination of y as a function of t, because x can easily be obtained from y by equation (1).

Dimensional theory. Let the physical constants needed for specifying the irreversible properties of a body be represented by $C_1, C_2, \ldots C_n$ and let X be the load at time τ. Suppose while τ varies from 0 to t the load passes through a maximum range R. Then the load history can be specified by R, t, and the geometrical shape of a diagram having X/R and τ/t for coordinates. Therefore

$$y = \text{funct}\ (R, t, C_1, C_2, \ldots C_n) \qquad (2)$$

in which the form of the function is unknown, but the same for all processes with geometrically similar load diagrams. As (2) is a qualitatively complete physical equation, it is subject to the usual methods of dimensional reasoning.

This leads to several interesting possibilities, notably the reduction of the number of independent variables confronting the experimenter, and the prospect of predicting effects outside the limit of direct measurement by observations on physically similar models.

In equation (2) with its N separate quantities $y, R, t, C_1, \ldots C$, there are $N - 1$ degrees of freedom, but Buckingham has shown[3] that dimensional requirements diminish this number by k, where k is the number of fundamental units needed for measuring the original N quantities. Now in treating irreversible processes where the physical state is held constant, x, X, and t are sufficient for fundamental units so that $k = 3$. Consider for example a body whose properties are fixed by $\nu = 3$ drift constants B_o, n, and β (defined by equations (7) and (13)). The dimensions of the original six quantities are $[y] = [x]$, $[R] = [X]$, $[t] = [t]$, $[B_o] = [xX^{-1}t^{-n}]$, $[n] = [1]$, and $[\beta] = [X^{-1}]$. Therefore (2) becomes

$$y = B_o R t^n \text{ funct } (\beta R, n) \qquad (3)$$

and it is clear that there are now only two independent variables, βR and n, instead of five. The procedure for model experiments can also be illustrated by equation (3), letting primed symbols refer to the model, others to the original. The condition for similarity is that the model be made from a substance having the same value of n, and loaded over a range R' such that $R'/R = \beta/\beta'$. The yield y at any time t can now be computed from the yield y' observed at time t' by the relation

$$\frac{y}{y'} = \frac{B_o}{B_o'} \cdot \frac{R}{R'} \cdot \left(\frac{t}{t'}\right)^n \qquad (4)$$

The load history diagrams for the model and original are to be kept geometrically similar.

Superposition theory. Direct calculation of the yield y at time t is possible on the basis of an assumption which may be called the principle of the superposition of elements of drift. By drift is meant the increase of displacement while the load is held constant. Imagine a small load ΔX applied instantaneously to a body which is in a normal state; that is, to a body which has rested undisturbed for a sufficient time so that all previous effects have sensibly died out. What happens? It is a matter of observation that the displacement does not stop with the immediate or elastic part x, but keeps on increasing. Under these circumstances, the yield Δy observed after a lapse of time T reckoning from the instant when the load was applied is termed the drift due to instantaneous loading. It can be written

$$\Delta y = \Delta X \cdot F(T) \qquad (5)$$

This equation serves to define the drift function $F(T)$, which is a purely empirical characteristic of the body.

[3] This JOURNAL 4: 347–353. 1914.

The fundamental physical assumption of drift superposition may now be stated in this way: The yield y at any time t is the algebraic sum of all the elements of drift generated by each previous load increment.

If this assumption is true, the general problem of irreversible time effects can be solved mathematically without further physical information than is already contained in the function F. The assumption implies that if two bodies have the same drift function F, they cannot differ in any of their remaining effects; and while this assumption is probably not precisely true even for moderate loads, it is certainly true as a first approximation, and therefore practically useful.

The following two-constant expressions have been used in aneroid barometer work:

$$F(T) = A(1 - e^{-mT}) \tag{6}$$

$$F(T) = BT^n \qquad (n<1) \tag{7}$$

and

$$F(T) = CT^{\frac{1}{2}}(1 - e^{-mT}) \tag{8}$$

while a formula equivalent to

$$F(T) = K(1 - e^{-\alpha\sqrt{T}}) \tag{9}$$

has been proposed by Michelson[4] for the drift due to torsion in a large number of substances. The coefficients A, B, C, K, m, n, α may depend on temperature and other physical conditions, including the load X itself; but are required by the superposition assumption to be independent of the load increment ΔX.

The principle of the superposition of elements of drift may be expressed mathematically thus,

$$y = \Sigma\, \Delta X.F(t - \tau) \tag{10}$$

in which y is the yield at the present time t, while ΔX denotes a load increment applied at some previous time τ. For convenience the argument T of the drift function has been replaced by its equivalent, $t - \tau$. Equation (10) can also be put into the form of a time-integral.[5]

$$y = \int_0^t \frac{dX}{d\tau} F(t - \tau)d\tau \tag{11}$$

[4] *Laws of elastico-viscous flow.* Proc. Nat. Acad. Sci. **3**: 319–323. 1917.

[5] The time-integral was made possible by suggestions of Dr. F. B. SILSBEE. Acknowledgments are due also to Dr. L. B. TUCKERMAN and Prof. P. W. BRIDGMAN for valuable suggestions. The first attempt at a general solution was completed in 1916 in connection with work on elasticity at Harvard University. It led to a formula which is equivalent to (10) but which was to be applied by the summation of series instead of by integration, and which also differed in that $F(T)$ represented the drift following a gradually applied load.

This is not an integral equation, for there is nothing unknown under the integral sign. It has sometimes been thought that integral equations would be indispensable in solving "heredity" problems, but such does not appear to be the case except when treating inertia.

The fact that the constants in the drift function may depend on the load could be shown explicitly by writing F as a function of two arguments, $t - \tau$ and X. Since the drift constants are sensitive to temperature change, this consideration has special importance for problems of thermal hysteresis where the load is itself a temperature change. It may often be sufficient to express F as the product of two factors, one of which, F_o, is independent of X, so that

$$F(t - \tau) = f(X).F_o(t - \tau)$$

and

$$y = \int_o^t \frac{dX}{d\tau} f(X) f_o(t - \tau) d\tau \qquad (12)$$

For example, if β denotes the fractional change in B with respect to load,

$$B = B_o(1 + \beta X) \qquad (13)$$

so

$$f(X) = 1 + \beta X$$

For vanishingly small loads $f(X)$ approaches unity and (12) reduces to von Schweidler's formula for residual effects in dielectrics.

When $f(X)$ is constant, the integration of (12) by parts gives $y = \int_o^t X\psi(t - \tau)d\tau$ in which $\psi(t - \tau)$ denotes the first derivative of the drift function $F(t - \tau)$, and in which it is understood that $X = 0$ when $\tau \lessgtr 0$. Writing ω in place of $t - \tau$ this reduces to

$$y = \int_o^\infty X\psi(\omega)d\omega \qquad (15)$$

which is Boltzmann's equation for the elastic after-effect in torsion wires. Boltzmann's formula is therefore a special case of (12) above, and a physical interpretation has been found for his arbitrary function $\psi(\omega)$ by identifying it as the slope of the drift curve.

Definition of ideal irreversibility. In all cases where some drift is generated whenever the load on a body changes, this fact alone necessitates qualitatively the existence of all the remaining irreversible effects such as the familiar hysteresis loop. Hence, it is of interest to compute the amount of each effect which would accrue from the simple addition of elements of drift even where it is not expected that the whole effect can be attributed to drift. In order to establish

standards of performance for the comparative study of different bodies, a process may be called ideally irreversible if the observed effect is in exact agreement with the amount calculated from the principle of superposition. The departure of an actual process from this arbitrary standard might be taken as a measure of the irreversible peculiarities of the body, just as the deviation of a real fluid from the equation of state of an ideal gas may be taken as a measure of its intrinsic properties.

Simple harmonic motion and the cyclic state. As an example of computation by the superposition method, consider a body subjected to a load

$$X = R \sin \omega\tau \tag{16}$$

If this body follows the drift function (6) with constants independent of load, integrating (11) gives

$$y = \frac{RA}{\sqrt{1 + \left(\frac{\omega}{m}\right)^2}} \left[\frac{\omega/m}{\sqrt{1 + \left(\frac{\omega}{m}\right)^2}} e^{-mt} + \sin(\omega t - \phi) \right] \tag{17}$$

where $\tan \phi = \omega/m$. From (1) the total displacement x can be found. After sufficient time that the exponential term of (17) has dwindled to an insignificant amount, the cyclic state may be considered established; the displacement then is given approximately by

$$x = \frac{R}{E} \left[1 + \frac{1}{2} AE \left(\frac{m}{\omega} \right) \right] \sin(\omega t - \Phi) \tag{18}$$

where $\tan \Phi = AE(m/\omega)$. The hysteresis loop will be found by eliminating the time ($\tau = t$) between the load equation (16) and the displacement equation (18). Since (16) and (18) represent two simple harmonic motions at right angles, of the same period but differing in amplitude and phase, the hysteresis loop will be an ellipse. The area of this ellipse will represent the energy dissipated into heat per cycle, after the cyclic state has been reached.

Calculation of recovery curve. Suppose a load R suddenly applied, kept on for a time interval t_0, then suddenly released. What will be the after-effect z (residual displacement) at an interval t' after the instant of release? Since x_e is now zero, the after-effect will equal the yield y at time $t = t_0 + t'$ due to a load increment $\Delta X = R$ at time $\tau = 0$ followed by a second increment $\Delta X = -R$ at time $\tau = t_0$. Hence by (10)

$$z = R[F(t_0 + t') - F(t')] \tag{19}$$

Thus the recovery curve can be constructed by making a tracing of the drift curve, inverting it and shifting it along the time axis by an amount t_0. The algebraic sum of the ordinates of these two curves forms the desired curve for z as a function of t'. This method has been applied with fair success to data furnished by Dr. C. E. Van Orstrand for the slow stretch in a steel tape over a period of four months, when suspended under tension. The greatest difference between the calculated and observed after-effect at any time during this long period was less than 9 per cent of the initial after-effect.

A similar check on equation (19) should be possible by reference to Michelson's data for torsion. His recovery curve formula may be written[6]

$$z = KRe^{-a\sqrt{t'}}\ (1 - e^{-a\sqrt{t_0}}) \qquad (20)$$

Substitution from (9) into (19) gives

$$z = KRe^{-a\sqrt{t'}}\ [1 - e^{-a(\sqrt{t_0 + t'} - \sqrt{t'})}] \qquad (21)$$

This, for small values of t', reduces to Michelson's experimental formula (20), but for large values it diverges. It is not possible to make an exact test of equation (19) without reference to the original observations, which were not given in the paper above cited.

These examples may suffice to make clear the general purpose of the superposition theory. It is not a molecular theory, neither does it aim to deduce a *priori* anything about the form of the drift function. It presupposes the availability of just such data as Michelson's drift curve (9) and then proceeds to develop the necessary interconnections between the drift and the remaining irreversible effects.

BOTANY. *Notes on the genus* Swartzia *in Panama and Guatemala.*[1]

HENRY PITTIER.

The genus *Swartzia* of the Caesalpiniaceae contains a large number of species, many of which are closely related, and the genus as a whole is badly in need of revision. In the present paper an attempt is made to systematize the representatives of the genus now known from Panama. A little known species of the genus from Guatemala is also described.

[6] *Op. cit.* See also Journ. Geol. **28**: —. 1920.

[1] Received February 11, 1921.

1. REVISION OF THE PANAMA SPECIES

Legume broad, long, and flat; racemes many-flowered, elongate; leaves pinnate, 5-foliolate. (PLATYPODA.) 1. *S. panamensis.*

Legume cylindrical, short; racemes 2- to 5-flowered; leaves mostly 1- or 3-foliolate, rarely 5-foliolate. (STRONGYLOPODA.)

Leaves unifoliolate. Petiole narrowly alate or scutellate at the apex; petal about 4 cm. in diameter. 2. *S. simplex.*

Leaves mostly 3-foliolate, sometimes 1- or 5-foliolate.

Stamens 20 or fewer, not conspicuously unequal. Flowers small, the petal hardly longer than the calyx. 3. *S. arborescens.*

Stamens numerous, conspicuously dimorphous, the longer ones 10 to 20, the smaller ones numerous.

Leaflets not over 10 cm. long, lanceolate, the petioles rather broadly winged. 4. *S. trifolia.*

Leaflets usually larger, ovate, the petioles rather narrowly winged.

Petal suborbicular, about 2 cm. in diameter. 5. *S. myrtifolia.*

Petal ovate-cordiform, about 2.5 cm. long and 3 cm. broad. 6. *S. darienensis.*

1. **Swartzia panamensis** Benth. in Mart. Fl. Bras. 15[2]: 38. 1870.

Deciduous (?) tree, 6 to 20 meters high, with short ascending limbs and elongate crown, the trunk seldom over 40 cm. in diameter, often distorted, the bark grayish, smooth.

Leaves 5-foliolate, pubescent, glabrate, with lanceolate-acuminate silky-pubescent caducous stipules; petioles 9 to 13 cm. long, almost terete; petiolules articulate, 4 to 6 mm. long; blades elliptic or ovate-lanceolate, rather long and narrowly acuminate, 8 to 18 cm. long, 3 to 6 cm. broad, dark green above, pale green beneath, the venation sparse, impressed above, prominent beneath, the 9 to 11 primary veins alternate, arcuate, transversely anastomosing.

Racemes solitary in the defoliated axils of the preceding season or in the axils of new leaves, very long (20 to 40 cm.), pendent, many-flowered, the bracts awnlike, up to 10 mm. long, caducous; rachis and pedicels minutely pubescent, the former thick and subangular; pedicels reflexed, clavate, about 2 cm. long; calyx opening irregularly by 4 or 5 reflexed lobes about 1 cm. long. Petal creamy yellow, almost square (31 mm. long, 29 mm. broad), unguiculate, hastate and emarginate at the base, subquadrilobate, with irregular margin; claw narrow, about 6.5 mm. long. Stamens very numerous, the larger ones 6 to 10, erect, with thick filaments 12.5 mm. long, the remaining small ones with threadlike filaments 15 mm. long and smaller anthers, their cells more or less parted at the base. Ovary short, flattened, entirely smooth, long-stipitate, with a short, blunt, hardly bent style; stipe 6 mm. long, the ovary and style about 5 mm. long; ovules 8 or fewer.

Legume single, 20 to 30 cm. long, 8 to 10 cm. broad, coriaceous, apiculate, dehiscent, 4- to 8-seeded; pedicel thick, 2 cm. long; stipe 1.5 to 2 cm. long; seeds large, irregularly sublenticular-ovate, 7 to 8.5 cm. long, 6 cm. wide, and 1.5 cm. thick, exarillate, dark brown.

SPECIMENS EXAMINED:

PANAMA: Rocky slopes along Chagres River near Alhajuela, flowers and fruit, May 13, 1911, *Pittier* 3520. Along Trinidad River, Canal Zone, near sea level, flowers, July 20, 1911, *Pittier* 4019. Around Port Obaldia, San Blas Coast, flowers, September 2, 1911, *Pittier* 4324.

Also recorded by Seemann from San Juan de Chagres and Hacienda de Juan Lanas. Seemann describes the racemes as being in pairs, a character not shown by the recent specimens, though these agree in the main with Bentham's short diagnosis. These collections from the shady forests of the littoral plain around Port Obaldia have broader and less coriaceous leaflets than those from the high banks of the Trinidad River or the rocky slopes of the Chagres gorges. In the first locality, too, the tree assumes more frequently an erect, regular shape, with a straight trunk. It seems that only the basal flowers of each spike bear a pistil; this part was missing altogether on several of the specimens I had occasion to dissect, and, so far as my experience goes, the pods invariably grow out of the 5 flowers nearest to the base of the raceme. Usually there is only one pod to each raceme, but two on the same peduncle are not uncommon. Completely developed seeds are seldom found. The trees on the Chagres River bore only new, incompletely developed leaves, although anthesis was rather advanced and even fully grown pods were present. These facts would indicate a deciduous species, the only one reported so far in this heterogeneous and not well defined genus.

2. **Swartzia simplex** Spreng. Syst. Veg. **2:** 567. 1825.

Small tree, 3 to 10 meters high, the trunk 10 to 15 cm. in diameter, straight or distorted, with smooth grayish bark, the branching sparse and divaricate.

Leaves unifoliolate, quite glabrous, more or less coriaceous, nitidulous, the primary veins numerous and subparallel; stipules setaceous, 5 to 8 mm. long, caducous; petiole 3 to 15 mm. long, terete and auriculate at the apex when very short, marginate and distinctly articulate at the apex when longest; blades ovate-oblong, rounded or subcuneate at the base, shortly obtuse-acuminate at the apex, 4 to 20 cm. long, 2 to 7 cm. broad, the venation prominent on both sides.

Inflorescences racemose, 2- to 6-flowered, axillary or terminal, 4 to 10 cm. long, the rachis glabrous; pedicels erect, 5 to 20 mm. long, obclavate; buds globose, 7 to 10 mm. in diameter; calyx opening by 4 irregular lobes; petal orbicular, about 4 cm. in diameter, pale yellow; long stamens 8 to 12, the anthers elongate-oblong; short stamens numerous, the anthers also smaller; ovary long-stipitate, quite glabrous, arcuate, 10- to 12-ovulate, the style arcuate and subulate.

Legume oblique-oblong, terete, up to 4 cm. long, 1.5 cm. in diameter, usually 1- or 2-seeded, in the latter case hardly contracted between the seeds.

TYPE LOCALITY: Trinidad.

SPECIMENS EXAMINED:

PANAMA: Chagres, *Fendler* 327. Agua Clara, Canal Zone, along Rio Trinidad, fruit, June 20, 1911, *Pittier* 3984. Culebra, Canal Zone, flowers, January 6, 1911, *Pittier* 2256. Penonomé and vicinity, fruit, March, 1908, *Williams* 396. Marraganti, South Darién, fruit, April 5, 1908, *Williams* 995.

3. **Swartzia arborescens** (Aubl.) Pittier.

Possira arborescens Aubl. Pl. Guian. **2:** 934. *pl. 355.* 1775[2].

Tree, 6 to 10 meters high, the branchlets glabrous or pubescent.

Leaves glabrous, 3-foliolate or sometimes 1-foliolate; stipules setaceous;

[2] For full synonymy see Fl. Bras. **15**[1]: 22. 1870.

rachis, including petiolar part, 1 to 4 cm. long, narrowly winged and auriculate at least under the terminal leaflet; leaflet blades ovate or ovate-elliptic, rounded or cuneate at the base, obtusely short-acuminate, subcoriaceous, lustrous, the terminal leaflet 5 to 10 cm. long, the primary veins numerous, parallel, and conspicuous.

Racemes axillary or terminal, the short slender glabrous peduncles with 2 to 4 flowers; pedicels filiform, 1 to 1.5 cm. long; bracts small, setaceous; bracteoles very small or none; buds quite glabrous, subglobose, hardly 4 mm. in diameter; petal orbicular, unguiculate, a little longer than the calyx; stamens 18 to 20, almost all equal, twice longer than the calyx, the anthers ovate; ovary stipitate, narrow, glabrous, 5- or 6-ovulate, attenuate to a short style, the stipe a little shorter than the calyx.

Legume short-stipitate, obliquely ovoid, long-acuminate, 4 to 5 cm. long, thick and carnose; seed oblique-ovoid, the aril lacerate, the raphe very prominent.

TYPE LOCALITY: Near the source of the Galibi River, French Guiana.

This species was collected on Tobago Island by Seemann (no. 1687), but I have seen no specimens of it.

4. **Swartzia trifolia** Pittier, sp. nov.

Small tree, 4 to 5 meters high, the trunk 8 to 12 cm. in diameter, the branchlets, leaves, and inflorescences entirely glabrous, the bark dark red and smooth.

Leaves usually 3-foliolate, seldom 5-foliolate, coriaceous; stipules setaceous, stiff, about 4 mm. long; rachis 2 to 5 cm. long, terete, winged-auriculate, the wings broader at the auricles; leaflets subsessile, the blades lanceolate, more or less oblique and rounded at the base, obtusely short-acuminate at the apex, the lateral ones 4.5 to 7 cm. long, 2 to 2.5 cm. broad, the terminal one 5.5 to 9 cm. long, 2 to 3.5 cm. broad, the primary veins about 16, anastomosing along the margin, the venation conspicuous on both sides.

Flowers not known.

Fruiting pedicel about 1 cm. long; stipe 8 mm. long; fruit glabrous, 1-seeded, ovoid, acuminate, 3.5 cm. long, 1.5 cm. broad between the sutures; seed ovoid-subreniform, 2.5 cm. long, brown and lustrous.

Type in the U. S. National Herbarium, no. 677726, collected on the savanna of La Tortuga, between El Boquete and Caldera, Panama, at an altitude of about 400 meters, in fruit, March 21, 1911, by H. Pittier (no. 3343).

This species is so well characterized by its peculiarly shaped leaves and narrow leaflets that even in the absence of the flowers I do not hesitate to describe it as new.

5. **Swartzia myrtifolia** J. E. Sm. in Rees' Cycl. **34:** *Swartzia* no. 5. 1819.

Small tree, the slender branchlets as well as the leaves and inflorescences glabrous or slightly pubescent.

Leaves 3-foliolate or sometimes 1-foliolate; stipules subulate, 3 to 4 mm. long; rachis slender, marginate and more or less distinctly auriculate below the insertion of the leaflets, 2.5 to 5 cm. long; leaflets subsessile, the blades ovate or ovate-oblong, rounded or cuneate at the base, obtusely short-acuminate at the apex, subcoriaceous, nitidulous, the primary veins numerous and prominent on both sides; lateral leaflets 6.5 to 8 cm. long, 3 to 4 cm. broad; terminal leaflet 6.5 to 14.5 cm. long, 5 to 7 cm. broad.

Racemes axillary or terminal, 2- to 5-flowered, about equaling the petioles; bracts small, setaceous; bractlets minute or none; peduncles short; pedicels slender, 1 to 2 cm. long; buds globose, 6.5 mm. in diameter; segments of the calyx 4, reflexed; petal yellow, orbicular, about 2 cm. in diameter; larger stamens 12 to 18, the anthers oblong; smaller stamens numerous, the anthers half shorter than those of the larger ones; ovary glabrous, narrow, recurved, long-stipitate, 8-to 10-ovulate, the style much shorter.

Legume nearly 2.5 cm. long, obliquely ovoid-oblong, short-acuminate.

TYPE LOCALITY: West Indies.

SPECIMENS EXAMINED:

PANAMA: Obispe Falls, Canal Zone, *Hayes*. Pinogana, South Darién, in forest, flowers, June 21, 1914, *Pittier* 6676.

6. **Swartzia darienensis** Pittier, sp. nov.

Small spreading tree, entirely glabrous, 6 to 8 meters high, with short trunk and pendent branches, the bark smooth, grayish.

Leaves 1- or 3-foliolate, membranous; stipules linear, 4 to 6 mm. long, caducous; petioles of the 1-foliolate leaves 5 to 7 mm. long, articulate and provided at the tip with 2 stiff acute auricles; rachis of the 3-foliolate leaves 3 to 6 cm. long, canaliculate, marginate, with acute auricles at the insertion of the leaflets; leaflets petiolulate, ovate-elliptic or broadly lanceolate, rounded or obtusely pointed at tip, the lateral ones 7 to 10 cm. long, 3 to 4 cm. broad, the terminal one and the blade of the 1-foliolate leaves 12 to 16 cm. long, 5 to 6 cm. broad; petiolules 4 mm. long; veins very thin, almost parallel, delicately reticulate-anastomosing.

Racemes axillary or terminal, often geminate, 3- to 5-flowered; bracts and bractlets linear, minutely pubescent, caducous; rachis 1.5 to 7 cm. long; pedicels 5 to 10 mm. long, clavate, pubescent; segments of the calyx 4, irregular, about 1 cm. long; petal pale yellow, irregularly ovate-cordiform, emarginate at the base, about 2.5 cm. long (including the claw, this 5 mm. long) and 3 cm. broad; larger stamens 4 to 9, the smaller ones very numerous, the anthers slightly larger in the former but all alike and broadly ovate or orbicular, with a dark connective; pistil incurved; ovary long-stipitate, 8-ovulate; style a little shorter than the ovary, capitellate.

Legume not known.

Type in the U. S. National Herbarium, no. 678872, collected on the rocky slope of Mamei Hill, near Gorgona, Canal Zone, Panama, July 6, 1911, by H. Pittier (no. 3800).

There is certainly a great deal of confusion as to the segregation of the several very nearly related forms of *Swartzia* in Panama, and the difficulty of separating them is increased by the vagueness of the descriptions and the lack of material. The species just described belongs without doubt to the polymorphous group of *S. myrtifolia*, but it seems not to agree with the description of any of the species published.

2. A LITTLE KNOWN SPECIES FROM GUATEMALA

Swartzia guatemalensis (Donn. Sm.) Pittier.

Swartzia myrtifolia var. *guatemalensis* Donn. Sm. Bot. Gaz. **33**: 251. 1902.

Section *Pteropoda*. Small tree, the branches slender, glabrous or minutely appressed-pubescent.

Leaves 3-foliolate or often reduced to the terminal blade, glabrous or more or less appressed-pubescent; stipules subulate or linear, minutely pubescent; petioles 1.5 cm. long in the simple leaves, 2.5 to 4 cm. in the compound leaves, glabrous, broadly alate, the wings up to 7 mm. broad, acute or rounded below the insertion of the leaflets; leaflets short-petiolulate, ovate-lanceolate, rounded at the base, obtusely long-acuminate, the main primary veins (of the terminal leaflets) 11 to 14, anastomosing along the margin, prominent on both sides, the intermediate veins numerous and parallel; lateral leaflets 3.5 to 9 cm. long, 1.5 to 4 cm. broad; terminal and single leaflets 8 to 16 cm. long, 3.5 to 6 cm. wide.

Inflorescences 2- to 5-flowered, axillary or terminal, the rachis slender, sparsely appressed-pubescent; pedicels subfiliform, 12 to 15 mm. long; buds subglobose or broadly ovoid, glabrous, about 9 mm. long; calyx opening by 3 irregular segments, almost 10 mm. long; petal short-unguiculate, broadly ovate, 16 mm. long, 22 mm. broad; longer stamens 8, the anthers elongate, recurved; smaller stamens numerous and short; ovary long-stipitate (the stipe 10 to 14 mm. long), 6- to 8-ovulate, glabrous, 6 to 8 mm. long, the style straight, subulate, 5 to 6 mm. long.

Legume not known.

Type collected by von Tuerckheim at Cubiquiltz, Alta Verapaz, Guatemala, in flower, May, 1901 (J. D. Smith, no. 7839).

This plant, described by Captain John Donnell Smith as a variety of *Swartzia myrtifolia*, differs from that species in several important particulars, such as the disparity between the lateral and terminal leaflets, the conspicuousness of the main primary veins, the long acumen of the blades, the broad wing of the petiole, the 3-laciniate calyx, the shape of the petal, the 8 long stamens (instead of 12 to 18), and the long-stipitate ovary. These characters are sufficient to justify specific rank for this interesting member of the Guatemalan flora.

OCEANOGRAPHY.—*Practical application of the electrical conductivity method of measuring sea water salinity.*[1] A. L. THURAS. (Communicated by S. W. STRATTON, Bureau of Standards.)

Heretofore the only reliable method of measuring the total salt content of sea water has been by chemically titrating for the amount of chlorine present. The relation of chlorine to the total salts being a constant, a measure of the salinity is thereby obtained. Salinity is defined as the number of grams of total salts in 1000 grams of sea water. The titration method, being a laboratory method, requires that the samples after collection be stored in suitable bottles until they can be tested on shore. The disadvantages of such a method are: the loss or breakage of samples, possible errors from evaporation and handling, and the great undesirability of not knowing the physical properties of the waters while they are being investigated.

[1] Received January 31, 1921.

During the Ice Patrol of 1920 an opportunity was given to use the electrical method of measuring sea water salinity on board ship. An apparatus consisting of instruments and parts secured from the Bureau of Standards was set up on shipboard and several hundred determinations of salinity were made. The operation of the apparatus was simple and convenient and at no time did weather conditions interfere with the measurements. This apparatus consisted of: a wheatstone bridge, a Leeds and Northrup alternating current galvanometer, a specially constructed electrolytic cell designed for a salinity recorder,[2] a hand regulated temperature bath, and a rebuilt 1/12 horse power direct current motor to give 120 volts, 60 cycles of alternating current when connected to 110 volts direct current. This machine was designed and built by Mr. A. J. Fecht of the Bureau of Standards.

All measurements were made at 25° C. and a table was prepared to give salinities directly from the balanced bridge readings. The complete apparatus was tested each day by standard sea water taken from a supply which had been carefully measured both by a chemical method and a density method[3] before beginning the cruises. This supply of sea water lasted throughout the cruises. The temperature of the electrolytic cell bath could easily be held to within 0.03° C., and the bridge, after balancing the moving coil of the galvanometer so that the center of mass was fairly near the axis of support, could be set to a value corresponding to 0.02 in salinity. No electrical capacity or inductance was necessary for balancing the bridge, and variations in the voltage and frequency of the generator had no appreciable effect on the bridge setting. With the rough apparatus used the determinations were accurate to 0.05 in salinity, or better than 0.02 of one per cent.

Since the electrical conductivity method may be satisfactorily used at sea to measure the salt content of ocean water, attention is directed to the references given in the foot notes which describe an apparatus which will give a continuous record of sea water salinity from a moving vessel. This instrument in conjunction with an instrument to record temperature, which has been constructed, would give the three most important physical variables of sea water, namely, temperature, salinity and density. Such records taken regularly over the same course would show monthly and yearly variations of these physical properties which might be of much scientific value.

[2] See this JOURNAL, **8**: 145, 680. 1918.
[3] See this JOURNAL, **7**: 605. 1917.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

PHILOSOPHICAL SOCIETY

837TH MEETING

The 837th meeting was held at the Cosmos Club, May 22, 1920, with President SOSMAN in the chair and 50 persons present.

The first two papers of the program were devoted to the general subject *Foreign laboratories and societies*, the speakers being C. E. MENDENHALL and H. L. CURTIS. Mr. MENDENHALL confined his remarks to his observations and experiences in England referring especially to the Royal Society, the Royal Institution and the Physical Society of London. Mr. CURTIS spoke of the French societies and laboratories and of the National Physical Laboratory of England.

Discussion: Messrs. SOSMAN, CRITTENDEN, HUMPHREYS, BOWIE, and WILLIAMSON took part in the discussion.

The last paper was by W. P. WHITE on *Three methods of promoting precision in thermostats*. Preliminary publication of this paper appeared in this JOURNAL.[1] The paper was discussed by Messrs. MENDENHALL, DICKINSON, MUELLER, and T. S. SLIGH.

838TH MEETING

The 838th meeting was held at the Cosmos Club, October 9, 1920. President SOSMAN presided and about 50 members and guests were present. The program was as follows:

S. J. BARNETT: *Further experiments on magnetization by rotation.*

This paper is a report of progress in the first part of a general investigation of the relations between magnetization and rotation designed to extend the earlier work in this field, to obtain more precise results, and especially to find out whether negative electricity with the known value of m/e is alone responsible for magnetism.

In earlier papers it has been shown that, if the slowly moving electron, with the value of m/e known from other experiments, is alone involved in the Ampéreian vortices, the rotation of a magnetic substance at an angular velocity of one revolution per second is equivalent to placing it in a magnetic field of strength -7.1×10^{-7} gauss directed along the axis of rotation. Two series of experiments made in 1914 and 1915, by a method of electromagnetic induction, gave 3.6 and 3.1, respectively, instead of 7.1, apparently indicating that negative electricity is chiefly responsible, but that positive electricity also is involved. Another alternative, on the assumption of the correctness of the experimental results, is that negative electricity alone is involved, but that it has, for the motions responsible for magnetism, a smaller value of m/e than that determined in known experiments.

Another series of experiments made in 1916 and 1917 by a magnetometer method gave the same sign as before, but gave numbers approximately 5 and 6 in place of 8.1. A few experiments made more than two years ago at the Ohio State University, where the earlier work was done, with copper sub-

[1] This JOURNAL, 10: 429–432. 1920.

stituted for the magnetic substance, indicated that a part of the effect in the magnetometer experiments was due to eddy currents, the effects of which appear to have been completely eliminated in the work done by the method of electromagnetic induction. This probably accounts for at least a part of the discrepancy between the results obtained by the two methods.

In new experiments performed under superior conditions in the non-magnetic experiment building of the Department of Terrestrial Magnetism, by the magnetometer method, considerable improvements have been made in the completeness with which the earth's field is compensated, in the elimination of mechanical and magnetic disturbances, and in other ways. The polar position of Gauss, which was earlier thought impracticable, has been substituted for the equatorial position, as it makes less difficult the elimination of eddy current effects and has other advantages. Eddy current effects have been more thoroughly studied by rotating copper and otherwise. The work is still in progress and other tests remain to be applied.

The most extensive observations have been made on a rod of Norway iron (for which observational curves were shown). Many observations have been made on a rod of cobalt, and some on rods of cold-rolled steel. All the rods gave values about one-half of 7.1 instead of 7.1, or even less, as in the experiments on iron by the method of electromagnetic induction, thus again indicating an effect of positive electricity or else indicating that negative electricity alone is involved, but has, for the motions responsible for magnetism, a smaller value of m/e than that determined in known experiments. Satisfactory experiments on nickel have not yet been made.

It is interesting to observe that, while all the sources of trouble have not yet been removed, the method is so sensitive that, in the later part of the night, when extraneous magnetic disturbances are least, the effect can be measured at even very small speeds. Curves between the scale readings for right and left handed rotations and the time were exhibited showing clearly the effect for cobalt at the speed 3/4 revolution per second.

The paper closed with a reference to recent experiments on the converse effect (rotation by magnetization). These experiments, on the theory which has been adopted by the investigators, but which involves an uncertain assumption with reference to the seat of the reaction to the resultant electron momentum produced on magnetization, also appear to indicate an effect of positive electricity or else the participation of negative electricity with a value of m/e different from that hitherto known.

The paper was illustrated by lantern slides, and was discussed by Mr. HUMPHREYS.

S. J. MAUCHLY: *Results of atmospheric electric observations made during solar eclipse of May 29, 1919, and summary of similar observations.*

The only atmospheric-electric observations made within the belt of totality during the total solar eclipse of May 29, 1919, appear to have been those by observers of the Department of Terrestrial Magnetism at Sobral, Brazil. These observations were in charge of Mr. ANDREW THOMSON, of the Department of Terrestrial Magnetism, who made measurements of the electrical conductivity of the air due to positive and negative ions, respectively. Mr. THOMSON was assisted by Mr. ANTONIO LIMA, a native of Brazil, who had been educated in the United States, and who made potential-gradient observations under Mr. Thomson's direction.

Owing to considerable cloudiness during the first hour of the eclipse, the conditions at Sobral were not so favorable for the detection of an eclipse-effect as those which favored the observations made for the Department of Terrestrial Magnetism by the author and others, in connection with the eclipse of June 8, 1918. However, in spite of the fact that clouds still remained, they did not obscure the Sun after a time corresponding to about 15 minutes before totality, and it was possible to note, in the results for the remainder of the eclipse, variations of the several elements similar to those observed at Lakin in June, 1918.

Briefly enumerated, the Sobral results indicate:

(*1*) A general potential-gradient *minimum* beginning just before totality and continuing until about 20 minutes after totality. The values during this period were abnormally uniform and about 20 per cent lower than those which obtained during the equal periods just preceding and following the one under consideration. (*2*) For both the positive and negative conductivity as determined by the ordinary Gerdien apparatus, a *maximum* of the order of 20 per cent, which set in just after totality and continued throughout most of the period of potential-gradient minimum. (*3*) That the air-to-earth current-density, as computed from potential-gradient and total conductivity, remained near the normal station value throughout the period in which obscuration exceeded 50 per cent, and was more constant than during any equal period of the forenoon.

In view of the general agreement between the results obtained at Lakin, in 1918, and at Sobral, in 1919, a detailed study was made of all available data concerning atmospheric-electric observations made during solar eclipses. It was found that the evidence as a whole is of a very conflicting nature unless special care is taken to note the apparatus and methods employed by the various observers, and the meteorological (especially cloud) conditions which prevailed during the observations.

Following these lines it was found that almost without exception the conditions attending previous observations were less favorable for the detection of an eclipse-effect than at Sobral and Lakin, and in nearly all cases where conditions were reasonably favorable the results for potential-gradient and conductivity were in substantial agreement with the foregoing.

The paper was illustrated by lantern slides.

L. A. BAUER: *Results of magnetic and meteorological observations during solar eclipse of May 29, 1919* (illustrated).

With the aid of magnetic data from nine stations within the region of visibility of the solar eclipse of May 29, 1919, five of these stations being those at which observations were made by the expeditions of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and from about eighteen cooperative stations distributed outside the region, the following main conclusions were drawn:

(*1*) Magnetic effects of appreciable and determinable magnitude were observed during the solar eclipse of May 29, 1919, at stations inside the region of totality as well as at certain stations in the sunlit region, the magnitude and character of the effects being similar to those observed during previous solar eclipses and showing a distinct connection with the eclipse circumstances. The magnetic data for stations in the night region of the globe did not exhibit similar effects.

(2) There were two principal variations (with some subordinate ones), as shown especially at stations near the totality-belt, having periods approximately that of the entire eclipse (5h. 10 m.) and that of the local eclipse (on the average about 2 hours from first to last contact). There are evidences that the effects continued for some time after the end of the eclipse at sunset on the southeast coast of Africa. The amplitude (semi-range) of the short wave was, on the average, about one-half of that for the long wave. In the case of the magnetic declination, for example, the amplitude of the long wave for stations inside or near the totality-belt approximated, on the average, one minute of arc, which was equivalent to a horizontal deflecting force of about 0.01 per cent that of the average west-east component of the Earth's magnetism.

(3) A preliminary analysis of the magnetic effects at stations within the region of visibility, or in close proximity, showed that the effects in declination and horizontal intensity were similar to those produced by a north-end attracting focus located in the vicinity of the shadow cone. With the aid of the vertical-intensity effects it was found that the eclipse magnetic system was composed of an external and an internal system of forces.

At 12h. 30m.G.M.T., May 29, 1919, just before the maximum development of the eclipse system, the north end attracting focus of the external system was located east-southeast of the shadow cone, and that of the internal system was to the northward of the cone and approximately northward of the point where the Sun and the Moon were in the zenith. The momentarily increased magnetization of the Earth for stations near the belt of totality of 0.012 per cent at 12h. 30m. corresponded to the amount associated with about a six per cent decrease in solar radiation. Equally interesting results were disclosed at other times; invariably the positions of the foci of the disturbing forces could be related to the momentary position of the shadow-cone. The indications are that the complete analysis of the eclipse magnetic system will show that it has characteristics analogous to those exhibited by the systems causing the solar-diurnal and the lunar-diurnal variations of the Earth's magnetism.

839TH MEETING

The 839th meeting was held at the Cosmos Club, October 23, 1920. President SOSMAN presided and 25 persons were present. The program was as follows:

WILLIAM BOWIE: *The Pan-Pacific Scientific Congress.*

The speaker presented a paper on the recent scientific conference for the exploration of the Pacific which was held under the auspices of the Pan-Pacific Union in Honolulu, August 2–20, 1920. In the winter of 1919–20, a committee of the National Research Council, formed to consider the scientific exploration of the Pacific, held several meetings at which the necessary preliminary steps were taken and then the activities were transferred to Honolulu where a local committee of scientists perfected arrangements for the conference.

At the conference were representatives of the United States, Canada, Japan, New Zealand, Australia, the Philippine Islands and Hawaii.

The organization of the conference was described, and the general resolutions and those resolutions bearing on the geographic subjects which were adopted by the conference were explained in some detail. The scientific

work considered under geography consisted of geodesy, topography, physical oceanography, terrestrial magnetism, and meteorology.

It was found that much work remains to be done in the Pacific in the various branches of science, and one of the purposes of the Congress was to present the evidence that would show that some central organization should be created that could assist and be a coordinating agency in scientific exploration in the Pacific region. It was the opinion of all those at the conference that the most urgent needs are in topographic mapping, including the shore line of the continents and islands, and oceanography, especially the configuration of the bottom of the ocean and the mapping of the direction and strength of the ocean currents. On this work, that is, topographic surveys and ocean charts, must be based much of the work in other lines of science.

The sessions of the conference were held at Honolulu, except that two general sessions, one on volcanology and one on seismology, were held at the volcano of Kilauea, which most of the delegates visited.

The speaker expressed appreciation of the hospitality and good will shown by the people of Honolulu to the members of the scientific congress.

It was stated that a publication will be issued by the Conference giving the resolutions and a brief history of the meeting. This publication will probably be distributed in the very near future. Later in the winter it is expected that one or more volumes will be published which will contain abstracts of minutes of the general sessions and of the meetings of the various sections, papers which were presented at Honolulu, and statements in regard to the various branches of science which are now in process of publication by the members of the conference. These later papers are expected to cover in more comprehensive form the problems of the scientific exploration of the Pacific region.

Discussion: Messrs. SILSBEE, SOSMAN, FERNER, MAUCHLY, and HUMPHREYS discussed Mr. BOWIE's paper.

P. V. WELLS: *The 1920 meeting of the British Association for the Advancement of Science.*

The meetings were held at Cardiff in the new public buildings which are grouped about a beautiful campus, leaving room at one end for the future Welsh Houses of Parliament. Sectional meetings opened on Tuesday morning (Aug. 24) with the presidential addresses, those of Prof. KARL PEARSON on Anthropology and of Prof. EDDINGTON on the Constitution of the Stars being particular features. The latter spoke of the radiative equilibrium in gaseous giant stars, their change in temperature from red to blue and final contraction to red dwarfs. Although the radiation within the giants is much like that of soft X-rays, their interior being at a temperature of millions of degrees, such stars are nearly heat tight. The radiation pressure prevents rapid shrinking and in fact overcomes gravitation in stars of much more than five times the mass of the sun, causing them to break up. ASTON's experiments leave no room for doubt that all the elements are built up of hydrogen and electrons, and the heat of the stars is accounted for by the mass radiated during their combination. "If indeed the sub-atomic energy in the stars is being freely used to maintain their great furnaces, it seems to bring a little nearer to fulfilment our dream of controlling this latent power for the well-being of the human race, or for its suicide."

In the evening President HERDMAN suggested a new Challenger expedition in his address on Oceanography. The next morning ASTON described his

epoch-making work on mass spectra proving atomic masses of all the elements to be whole numbers excepting hydrogen. Neon, chlorine, argon and many other elements are mixtures of isotopes of different masses but of the same atomic number (the number of positive charges on the nucleus which determines its atomic properties).

Sir ERNEST RUTHERFORD followed with a short description of his work on the disintegration of nitrogen and other gases into hydrogen particles moving with greater velocity than the bombarding α-particles themselves. Thus without doubt the hydrogen nucleus is the positive electron and stable groups of minute hydrogen particles, bound together by the much larger negative electrons, such as the helium nucleus (α-particle) form the nuclei of all the heavier atoms.

Especially interesting also were the remarkable discussion on the Origin of Spectra led by NICHOLSON, the note of Sir OLIVER LODGE on Relativity and the reply of Pres. EDDINGTON, the evening discourse of Sir RICHARD GLAZEBROOK on Aircraft and the vote of thanks moved by Dr. STRATTON of our Bureau of Standards. The wealth of things of interest in other branches of science, and the pleasant excursions of all sorts filled every moment of a busy and delightful week.

Discussion: The paper was discussed by Messrs. SILSBEE and SOSMAN.

840TH MEETING

The 840th meeting was held at the Cosmos Club, November 6, 1920, with President SOSMAN in the chair and 32 persons present. The following program was given:

E. F. MUELLER and T. S. SLIGH, Jr.: *The hypsometer as a precision instrument* (presented by Mr. Mueller).

A very simple form of hypsometer, consisting of a nearly closed space into which steam from a boiler can be admitted, will serve to maintain a temperature in the steam space which differs at most by a very few hundredths of a degree from that corresponding to saturated steam at the prevailing atmospheric pressure. The well-known Rudberg or Regnault hypsometer is a very simple apparatus, and is capable of serving the requirements of all but the most precise thermometric measurements. In the more elaborate designs which have been developed at the International Bureau and at the Reichsanstalt, the design has been largely influenced by such considerations as the desirability of being able to read mercurial thermometers in either a horizontal or a vertical position, of measuring accurately the difference between the pressure of the steam and atmospheric pressure, or of avoiding superheating of the steam, the last named feature being particularly emphasized. Apparently the question of purity of material, or the possibility of the steam being mixed with air, has received only incidental consideration.

In the design of a new portable hypsometer, advantage was taken of the difference in density of steam and air to insure rapid removal of air from the steam space by introducing the steam into this space at the top. This has the further advantage of rendering the temperature stable with no appreciable excess pressure in the steam space thus dispensing with the water manometer. Electric heating is used and the volume of the boiler is small, so that heating up is rapid. Two sheath heating coils are used which, connected in parallel, provide rapid heating, and connected in series suffice for regular operation.

Experiments with heat inputs from 125 to 640 watts indicate that such

variations produced no measurable effect in the temperature of the steam space, thus indicating the absence of both superheating and excess pressure in the steam space.

Extended experiments were made to determine the reasons for the fortuitous errors of about 0.005° usually observed in precise steam point determinations. Apparently such errors are due to irregular fluctuations in atmospheric pressure and to errors in measurement of barometric pressure, indicating that improvements in this respect will require the use of a closed system and better temperature control of the barometer.

The instrument described was exhibited and operated.

Discussion: The paper was discussed by Messrs. WHITE, TUCKERMAN, SOSMAN, HEYL, and BEALL.

T. S. SLIGH, JR.: *Thermostatics.*

In this paper it is shown that the degree of temperature regulation attainable in a thermostated bath depends upon the thermal and space relations of the various elements of the bath to an equal if not greater extent than upon the characteristics of the thermoregulator alone.

The three desirable characteristics of a thermoregulated bath are: steadiness of controlled temperature, constancy of controlled temperature, and range of regulation.

Steadiness is measured in terms of the periodic variations of the instantaneous temperatures of the working-space as the regulator operates. It is desirable that the amplitude of this variation be small and that the period be short.

Constancy is measured in terms of the variations of the time-average temperature of the working-space as measured over a complete cycle of operation of the regulator with variations of average rate of energy gain or loss from the bath.

Range may be measured in terms of the average energy input controlled by the regulator or its equivalent, the number of degrees of change in surroundings temperature for which the regulator is able to compensate.

It is shown by reference to the characteristic equations for thermostatic regulators as derived in the author's paper[1] that some gain is to be secured by increasing the sensitivity of the regulator but, in view of present practice, it seems that increased constancy, steadiness, and range can best be secured by reducing the over-all lag of the system. This lag is made up of the lag of the heater, the lag, or lapse, due to the time required for the water to circulate from the heater to the regulator bulb, and the lag of the regulator bulb. The lag of the heater may be made small by the use of a heating coil of small heat capacity and large dissipating surface. The stirring lapse may be made small by securing vigorous circulation and by placing the regulator bulb as close to the heater as is possible without the inclusion of a temperature gradient region between the regulator bulb and the working space. The regulator lag may be made small by the use of bulbs of large surface volume ratio and by securing a vigorous circulation of water past the bulb, thus reducing the thermal resistance of the bulb surface.

Great steadiness together with large range may be secured by the use of the oscillating contact regulator which is described in the paper referred to above.

[1] *Some characteristics of the Gouy thermoregulator.* Journ. Am. Chem. Soc. Jan. 1920.

Great range together with constancy may be realized by the use of an auxiliary compensator which consists of a motor geared to the contact of the rheostat which controls the fixed heat supply to the bath. The direction of rotation of this motor is periodically reversed by a relay in such a manner that the fixed heating tends to be slowly increased or decreased during the parts of the cycle of operation of the regulator during which an increased or decreased supply of energy is required by the bath. Thus the fixed heating is increased or decreased as the bath requires an increased or decreased supply of energy over one or more complete cycles of operation of the regulator.

It is seen that this method of regulation requires only a *temporary* departure of the bath temperature from its normal value in order that a permanent change in the heating be effected, whereas without the auxiliary compensating mechanism the change in the heating persists *only* during the time that the bath temperature remains above or below normal.

The auxiliary compensator may be used in connection with the oscillating contact regulator to secure steadiness, constancy, and range to a high degree.

Discussion: This paper was discussed by Messrs. WHITE, BEALL, BREIT, TUCKERMAN, FERNER, WENNER, ADAMS, VAN DUSEN, HEYL, MUELLER, and SOSMAN.

S. J. MAUCHLY, *Recording Secretary*

SCIENTIFIC NOTES AND NEWS

MATTERS OF SCIENTIFIC INTEREST IN CONGRESS.[1]

The third session of the Sixty-sixth Congress convened on December 6, 1920.

Under a special rule adopted on December 14, the joint resolution (S.J. 191) to create a joint commission on reorganization of the administrative branch of the Federal Government was brought up for two hours' debate on that date and passed by the House, having already passed the Senate on May 10. The bill became Public Resolution No. 54 on December 30 without Executive approval. The resolution requires the Committee to make a report in December, 1922. Mr. SMOOT announced in February that the Committee would do the work personally and would not turn it over to the Bureau of Efficiency or any other governmental agency. Considerable shifting and rearrangement of the scientific bureaus has been predicted as a probable outcome of the reorganization movement.

The House Committee on Patents recommended on December 10 that the Nolan Patent Office bill (H.R. 11984) be sent to conference, but unanimous consent for such reference was refused in the House. Later, on December 14, the bill was sent to conference, and hearings were reopened by the conference committee in January. Section 9 of the bill, providing for the issuance of patents to Federal employees, continued to meet with opposition from commercial and industrial interests, but was retained in the bill. The House agreed to the conference report on February 16. Opposition developed in the Senate, and the bill did not reach final action before the end of the session on March 4.

The bill for Federal supervision of the nitrate plants (S. 3390), including provision for research on the fixation of nitrogen, was made the unfinished business in the Senate on December 15. After several debates and the adoption of a number of amendments, the bill passed the Senate on January 14. The House took no final action.

The American Society of Zoologists, at its annual meeting on December 28–30, 1920, passed resolutions protesting against the passage of that part of H.R. 7785 (the scientific apparatus tariff bill) which abolishes the "duty-free privilege" to educational institutions. Occasional protests against this feature of the bill have been discussed in current scientific and technical periodicals. This feature of the bill was brought up in a hearing on the Fordney emergency tariff bill before the House Committee on Ways and Means on February 14, and the sentiment of the Committee seemed to be strongly in favor of eliminating the duty-free privilege on chemical glassware, chemical porcelain and apparatus. The Fordney bill passed both houses, but was vetoed by the President.

[1] Preceding report: This JOURNAL, **10**: 423. 1920.

As for the special bill for a tariff on scientific supplies (H.R. 7785), although it had passed the House as long ago as August 2, 1919, the Senate took no final action and it lapsed with the adjournment on March 4.

A bill "to fix the metric system of weights and measures as the single standard for weights and measures" was introduced in the House by Mr BRITTEN on December 29 (H.R. 15420), and in the Senate by Mr. FRELINGHUYSEN (by request) on December 18 (S. 4675). The bills are said to have been "fathered" by the World Trade Club of San Francisco. They were referred to the respective weights and measures committees and no further action was taken.

The Smith-Towner bill to create a Department of Education (S. 1017 and H.R. 7) after lying dormant through nearly the entire life of the Congress, was reported in the House on January 17 and in Senate on March 1, but progressed no further.

A step toward the erection of the proposed building for the National Academy of Sciences was taken in the introduction of S. 4645, "to authorize the Commissioners of the District of Columbia to close upper Water Street between 21st and 22d Streets, NW." The bill passed the Senate on February 24, but advanced no further.

With the adjournment of the Sixty-sixth Congress at noon on March 4, various other bills and resolutions which are of interest to scientists and which have been commented upon in this section of the JOURNAL either perished in committees or at the intermediate stage of progress last noted in these columns.

NOTES

The twenty-third edition of the Directory of the Washington Academy of Sciences and its affiliated societies (the "Red Book")appeared early in March. This edition contains 2779 names and data concerning 35 societies.

The following lectures have been presented before the Physics Club of the Bureau of Standards during the present season: November 1, 1920, W. J. HUMPHREYS: *The roaring mountain and associated phenomena.* November 15, J. C. KARCHER: *X-ray spectroscopy, with special reference to X-ray spectra in vacuo.* November 29, R. C. TOLMAN: *The rate of chemical reaction.* December 13, F. C. BROWN: *Propagated light sensitiveness of selenium.* January 10, 1921, I. G. PRIEST: *Chicago meeting of the Optical Society of America;* E. A. ECKHARDT: *Chicago meeting of the American Physical Society.* January 24, R. S. WOODWARD: *The doctrine of relativity and Einstein's theory of gravitation.* February 7, P. V. WELLS: *Statistics, or the theory of sampling, and its relation to the physical sciences.* March 7 and 21, P. D. FOOTE: *Modern developments of the Bohr theory of atomic structure.*

The following-named officers were elected at the annual meeting of the Scientific-Technical Section of Federal Employees Union No. 2 in December: *President:* J. FRANKLIN MEYER, Bureau of Standards; *Vice-President:* GEO. A. HILL, U. S. Naval Observatory; and *Secretary-Treasurer:* C. T. JARVIS, Bureau of Education. At the meeting of the Board of Delegates on February 24, D. R. GLASS, Public Health Service, was elected *Secretary-Treasurer,* to succeed C. T. Jarvis, resigned. The following were named members of the *Executive Committee:* V. K. CHESNUT, Bureau of Chemistry; Miss EUNICE OBERLY, Library, Department of Agriculture; W. C. THURBER, Patent Office; and W. I. SWANTON, Reclamation Service.

The section of vertebrate paleontology of the National Museum has just

received, from the Upper Cretaceous deposits along the Red Deer River of Alberta, Canada, an exhibition specimen of a skull of the crested dinosaur *Stephanosaurus*, a unique genus heretofore unrepresented in the collections. *Stephanosaurus* is remarkable on account of the development on the top of the skull of a high thin bony crest resembling that of the living Cassowary.

Dr. D. BORODIN, Russian economic entomologist, has been visiting Washington and has been looking up Russian entomological literature in the libraries of this city. Before the revolution Dr. Borodin was director of the Agricultural Experiment Station at Poltawa, in southern Russia.

The honorary degree of Doctor of Sciences was conferred upon Messrs. FREDERICK V. COVILLE, botanist in the Bureau of Plant Industry, U. S. Department of Agriculture, and FRANK SPRINGER, paleontologist in the U. S. National Museum, at the centenary graduation exercises of George Washington University on February 22.

Mr. C. R. DELONG has been appointed chief of the chemical division of the U. S. Tariff Commission, succeeding Dr. GRINNELL JONES, who has returned to Harvard University but retains a connection with the Commission in an advisory capacity. The other members of the chemical staff of the Commission are Messrs. S. D. KIRKPATRICK, W. N. WATSON, and A. R. WILLIS.

Dr. ALFRED DOOLITTLE, professor of mathematics and instructor in astronomy at the Catholic University since 1898, died on February 23, 1921.

Dr. PENTTI ESKOLA, of the Geological Survey Commission of Finland, is engaged in petrologic research at the Geophysical Laboratory of the Carnegie Institution of Washington.

Dr. MAURICE C. HALL, of the Bureau of Animal Industry, has been elected secretary of the Washington Alumni Chapter of the Society of the Sigma Xi. The Society plans to have a series of informal inspection trips to the scientific institutions of the city.

Dr. L. I. SHAW, of the Bureau of Mines, has been elected treasurer of the Chemical Society, succeeding the late FREDERIC P. DEWEY.